

# Synthesis And Characterization of Starch-Based Bioplastics: Impact of Formulation Variables

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doi.org/10.64643/IJIRTV12I9-196009-459

**Abstract**—This study aimed to synthesize and characterize starch-based bioplastics from two abundant sources, cornstarch and potato starch, and evaluate the effects of glycerol content, acetic acid concentration, and pH on their physical and chemical properties. Nine bioplastic samples were prepared by solution casting with varying compositions of starch, glycerol(1-10ml), and acetic acid (0–10%), followed by neutralization and drying. The films were characterized through visual inspection and absorption tests in water, acetic acid (5%), and sodium hydroxide (0.1N) solutions. Potato starch-based bioplastics exhibited higher flexibility but greater water absorption (up to 112.8%) compared to cornstarch-based films. Increased glycerol content enhanced elasticity but also increased hydrophilicity. Samples synthesized with higher acetic acid concentration or without neutralization showed significantly elevated water and acid absorption. All samples demonstrated lower absorption in alkaline medium than in acidic medium. The properties of starch-based bioplastics can be effectively tailored by adjusting the starch source, plasticizer content, and synthesis pH. While potato starch offers better flexibility, cornstarch provides greater stability in moist environments. Optimization of these parameters is crucial for developing bioplastics suitable for specific applications such as biodegradable packaging.

**Index Terms**—Biodegradable Materials, Bioplastic, Cornstarch, Glycerol, Potato starch, Plasticizer, Water Absorption.

## I. INTRODUCTION

Starch is a key renewable biopolymer for producing biodegradable plastics, with its properties varying significantly based on botanical source. Cornstarch and potato starch are two of the most abundant types, differing in amylose/amylopectin ratio, granule structure, and functional behavior, which leads to distinct characteristics in bioplastic films (N. Singh, J. Singh, and N. S. Sodhi, 2002). The final properties of

these starch-based materials are critically influenced by formulation parameters. The addition of plasticizers like glycerol is necessary to impart flexibility but often increases water sensitivity.

Furthermore, the pH and acid concentration during synthesis can modify starch gelatinization and crosslinking, affecting the film's mechanical integrity and hydrophilicity (L. S. Zárate-Ramírez, A. Romero, C. Bengoechea, P. Partal, and A. Guerrero, 2014). A direct, systematic comparison of how these variables—starch type, plasticizer content, and synthesis pH—jointly determine the environmental stability of the bioplastics is needed for targeted application development. This study therefore synthesizes bioplastics from corn and potato starch to evaluate the effects of glycerol concentration, acetic acid level, and pH on their physical characteristics, water absorption, and resistance to acidic and basic conditions.

## II. MATERIAL AND METHODS

### A. Materials

Commercial grade corn starch and potato starch were used as polymer matrices. Glycerol was used as a plasticizer. Acetic acid (5%) and sodium hydroxide (0.1 N) were used for pH adjustment during synthesis and for absorption tests. All solutions were prepared using distilled water.

### B. Synthesis of Bioplastic Films

Bioplastic films were prepared using a solution casting method. A base formulation consisted of 5 g starch, 50 mL distilled water, 4 mL glycerol, and 6 mL of 5% acetic acid. The mixture was heated at 70–80 °C under continuous stirring for 10–15 min until a translucent gel formed. The pH was neutralized by adding 6 mL of 0.1 N NaOH. The gel was cast into Petri dishes and

dried at room temperature for 48 h (Fig 2). To study the effect of different variables, nine distinct samples were prepared by modifying the base formulation as detailed in Table 1. Variations included the starch source (corn, potato, or a 1:1 blend), glycerol content (1, 4, or 10 mL), acetic acid concentration (2%, 5%, or 10%), and the omission of neutralization to create an acidic film. The synthesis of bioplastic films via solution casting was adapted from established methods [R. Sen, A. Maan, and U. Pandel, 2017; P. Sonawane, A. Panchal, S. Naik, B. Mundaye, and U. Padalia, 2021], with specific modifications as outlined in Table 1.

Table I. Composition of bioplastic samples

Sample No.	Potato starch	Corn Starch	Glycerol	Vinegar	0.1N NaOH	Water	Formulation Note
1.	5 g	-	4 ml	-	-	50 ml	No acid added, not neutralized.
2.	-	5 g	4 ml	6 ml (5%)	6 ml	50 ml	Standard cornstarch film
3.	5 g	-	4 ml	6 ml (5%)	6 ml	50 ml	Standard potato starch film.
4.	2.5 g	2.5 g	4 ml	6 ml (5%)	6 ml	50 ml	Composite starch (1:1 blend).
5.	5 g	-	4 ml	6 ml (10%)	6 ml	50 ml	High acetic acid concentration.
6.	5 g	-	4 ml	6 ml (2%)	6 ml	50 ml	Low acetic acid concentration.
7.	5 g	-	10 ml	6 ml (5%)	6 ml	50 ml	High glycerol content
8.	5 g	-	1 ml	6 ml (5%)	6 ml	50 ml	Low glycerol content
9.	5 g	-	4 ml	10 ml (5%)	-	50 ml	Acidic, not neutralized

### III. OBSERVATIONS

#### A. Visual and Physical Characteristics

The physical properties of the bioplastic films varied significantly with composition (Table 2). Films with higher glycerol content (Sample 7, 10 mL) were soft, sticky, and highly flexible. In contrast, films with low glycerol (Sample 8, 1 mL) were tough, brittle, and translucent. Potato starch-based films (Sample 3) were generally softer and clearer. The composite starch film (Sample 4) exhibited a grainy texture and moderate flexibility.

#### B. Water Absorption

Water absorption was calculated using equation (1). It was found to be highly dependent on formulation (Table 2). Potato starch film (Sample 3) absorbed 51.88% water, while cornstarch film (Sample 2) absorbed 56.5%. The composite film (Sample 4) showed the highest absorption among the standard, neutralized samples (65.21%). The most significant

#### C. Characterization

The dried films were visually evaluated for texture, flexibility, elasticity, and brittleness.

Pre-dried film samples were weighed (initial dry weight,  $W_i$ ) and immersed in 50 mL of test medium—distilled water, 5% acetic acid, or 0.1 N NaOH—for 24 h at room temperature. After immersion, samples were surface-dried and weighed again (final weight,  $W_f$ ). The percentage absorption ( $A\%$ ) was calculated as:

$$A\% = [(W_f - W_i) / W_i] \times 100 \quad (1)$$

effects were observed with variations in glycerol and pH. The high-glycerol film (Sample 7) absorbed 22.0% water, while the low-glycerol film (Sample 8) absorbed 73.68%. The acidic, non-neutralized film (Sample 9) exhibited extreme hydrophilicity, with the highest absorption of 112.82%.

#### C. Acid and Base Absorption

Acid and base absorption was also calculated using Equation (1). Acid absorption followed a trend similar to water absorption but with generally higher values (Table 2). The non-neutralized acidic film (Sample 9) showed an AA of 60.13%. The low-glycerol film (Sample 8) exhibited the highest absorption (104.08%). Cornstarch film (Sample 2) was more resistant to acid (42.85%) than the standard potato starch film (Sample 3, 21.83%). In contrast, base absorption values were, on average, lower than those for acid across all samples (Table 5), indicating better stability in alkaline conditions. It

ranged from 24.36% (potato starch, Sample 3) to 84.61% (low-glycerol film, Sample 8).

Table II. Physical characteristics and absorption properties of bioplastic samples

Sample	Overall Nature	Water Absorption %	Acid absorption %	Base Absorption %
1.	Soft, Translucent	51.46	58.18	54.36
2.	Soft, Clear	56.5	42.85	39.43
3.	Soft, Clear, Sticky	51.88	21.83	24.36
4.	Soft, Translucent	65.21	77.63	65.60
5.	Sticky, Clear, Rubbery	45.23	63.26	60.71
6.	Soft, Clear, Thin	29.54	58.33	57.30
7.	Translucent, Sticky	22	77.22	69.24
8.	Translucent, Tough, Brittle	73.68	104.08	84.61
9.	Translucent, Rubbery	112.82	60.13	56.13



Fig 1. Samples after drying



Fig 2. samples poured in petriplate

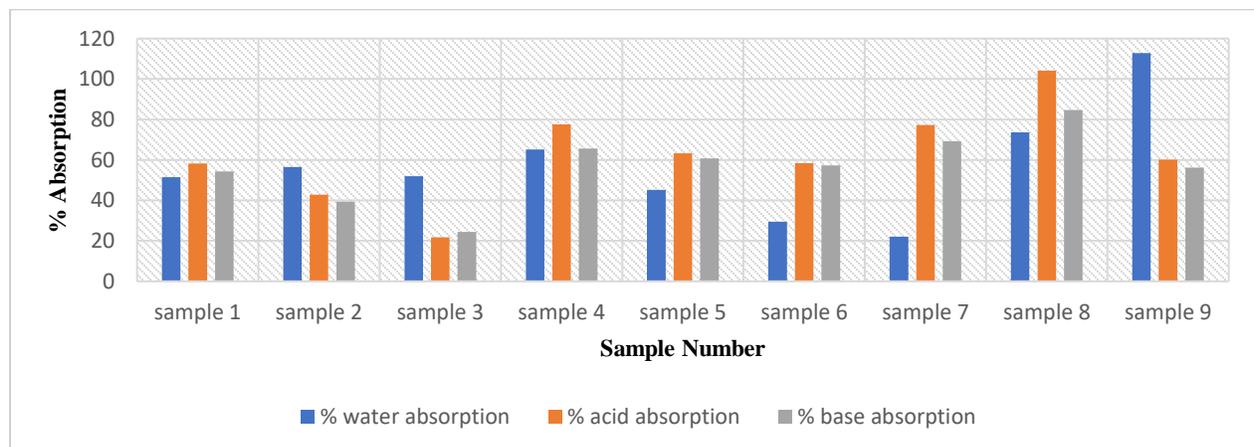


Fig 3. Absorbance of varying samples

#### IV. RESULTS AND DISCUSSION

The properties of the starch-based bioplastics changed a lot based on three factors: the starch source, plasticizer content, and synthesis pH. This matches

what we know about biopolymer science. The difference in water absorption between cornstarch (Sample 2, 56.5%) and potato starch (Sample 3, 51.88%) films comes from their unique macromolecular structures. Potato starch has more amylopectin. This branched structure makes a looser

matrix that can hold more water. This aligns with findings by E. Basiak, A. Lenart, and F. Debeaufort (2017). Higher amylose in cornstarch usually means a denser, more organized structure. This results in less swelling power (N. Singh, J. Singh, and N. S. Sodhi, 2002). However, in this study, the composite starch film (Sample 4) showed the highest water absorption (65.21%), suggesting that mixing starches did not combine their properties but may have introduced structural irregularities that increased hydrophilicity. Glycerol content had an unexpected effect on absorption properties. As a hydrophilic plasticizer, glycerol disrupts intermolecular hydrogen bonds between starch chains, increasing free volume and polymer mobility (F. M. Fakhouri, D. Costa, F. Yamashita, S. M. Martelli, R. C. Jesus, *et al.*, 2013). This explains the high flexibility of high-glycerol films (Sample 7). Contrary to the typical trend, Sample 7 (10 mL glycerol) showed lower water absorption (22.0%) than Sample 8 (1 mL glycerol, 73.68%). This anomaly might happen because of too much glycerol. This can create a gel-like structure that keeps water out. It could also be due to differences in film density and shape. The low-glycerol film (Sample 8) was brittle and showed the highest acid absorption (104.08%), indicating that insufficient plasticization creates a rigid, micro-cracked matrix prone to rapid fluid uptake.

The pH during synthesis was a critical determinant of environmental stability. Sample 9, the non-neutralized acidic film, showed the highest water absorption at 112.82%. This confirms that acid treatment breaks down starch chains. As a result, it increases porosity and hydrophilicity (L. S. Zárate-Ramírez, A. Romero, C. Bengoechea, P. Partal, and A. Guerrero, 2014). Almost all samples demonstrated lower absorption in alkaline medium (NaOH) than in acidic medium (CH<sub>3</sub>COOH), highlighting their greater stability in basic conditions. The alkaline medium likely doesn't catalyze the same chain scission as acid. This helps keep the film's integrity intact.

Overall, the results demonstrate that starch-based bioplastics are highly tunable materials. The starch source sets the basic mechanical and barrier properties. Glycerol concentration and synthesis pH are key factors for adjusting flexibility and resistance to the environment. For applications requiring moisture resistance (e.g., dry food packaging), cornstarch with optimized, moderate glycerol content

is preferable. For applications needing flexibility and some hydrophilicity, potato starch with more plasticizer is a good option.

## V. CONCLUSION

This study synthesized and analyzed bioplastics from corn and potato starch. It showed that their functional properties can be easily adjusted through formulation. Cornstarch-based films provided greater structural stability, while potato starch-based films offered superior flexibility. Glycerol content was key. It boosted elasticity but also made the material more prone to water and acid absorption. The synthesis pH had a big impact. Non-neutralized acidic films showed very high hydrophilicity. Overall, the findings indicate that starch-based bioplastics can be used for specific applications, but their composition must be carefully optimized. Cornstarch formulations with moderate plasticizer levels can resist moisture well. In contrast, potato starch with more glycerol is better for flexible needs. Future work should aim to strengthen these bioplastics. Using natural fillers or crosslinkers can boost their durability. This will help make them more suitable for commercial use.

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